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GB 0545271 A US 4637471 A US 4315542 A
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(54) Apparatus for circulating fluid

(57) Apparatus (1) for circulating fluid in a borehole comprises a body member (2) having a fluid outlet (8). An isolation sleeve (9) is movably mounted on the body member (2) for movement between an open position in which fluid may flow out of the outlet (8) and a closed position. The isolation sleeve (9) is moved to its open position against the action of spring 10 by engaging shoulder 20 with the top of the lining and setting down on the tubing string. In a second embodiment (not shown) the outlet is opened when the lower end of the tubing string engages the bottom of the borehole.

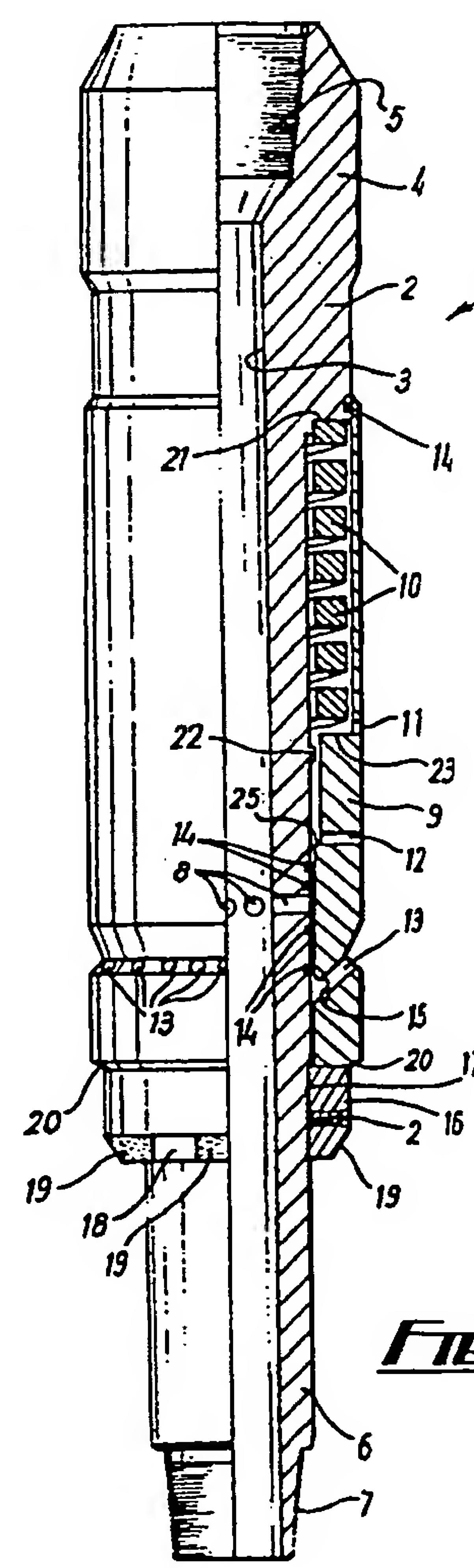

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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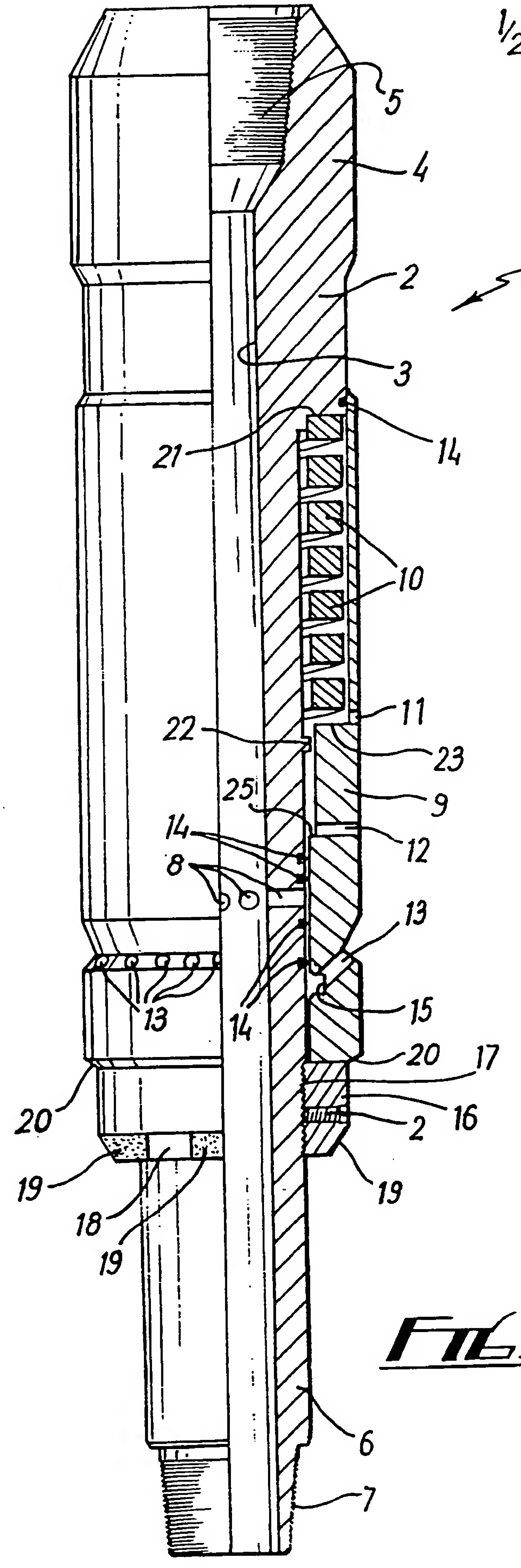

FIG. 1

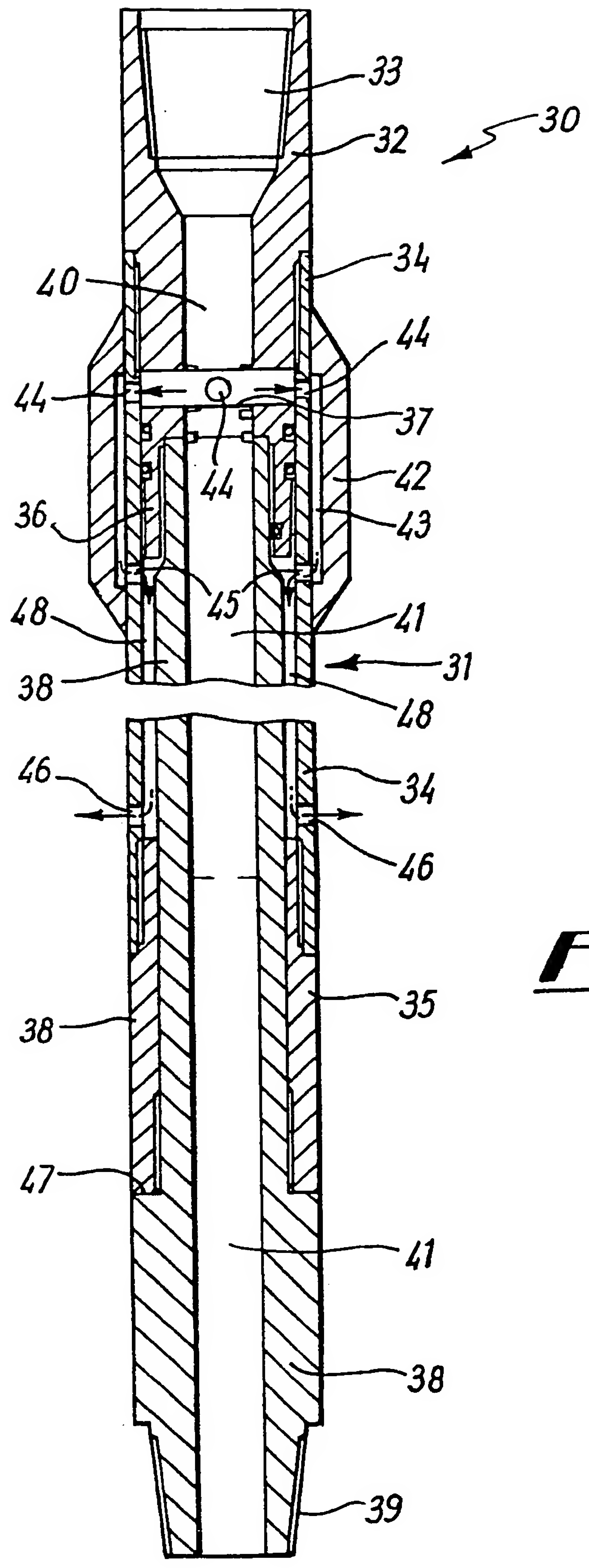

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FIG.2

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"Apparatus for Circulating Fluid"

The invention relates to apparatus for circulating fluid and in particular, apparatus for circulating fluid in a borehole.

It is common practice to install liners within a borehole which has been drilled and after installation of the liners it is generally necessary to clean out the inside of the liner to wash away any debris or other contaminants.

Generally, the liner is in the form of a cylindrical tube which has a relatively small internal diameter compared with the diameter of casing lining the borehole immediately above the liner. To effectively clean out inside the liner, high flow rates are generally required to create turbulence to aid the cleaning out process. Generally, the clean out procedure is carried out by first passing cleaning liquid through the drill string to the lower end of the liner at a high flow rate so that the cleaning fluid flows turbulently up the annulus between the inside of the liner and the outside of the drill-pipe and then into the casing above the liner.

However, because of the difference in volume between the liner and the casing above the liner, after the cleaning fluid passes the top of the liner and enters the relatively large volume of the casing, the flow rate of the cleaning fluid in the casing above the liner is greatly reduced and any cleaning action becomes negligible.

Hence, it is generally necessary after passing cleaning fluid through the liner to then pass further cleaning fluid from the drill-pipe into the casing at a location above or adjacent the top edge of the liner, so that a high flow rate and hence turbulence of the cleaning fluid can be obtained in the casing. Therefore it is generally necessary to have some device at or adjacent to the top end of the liner which can be operated downhole to either circulate fluid through the length of the drill string to the lower end of the liner or which can direct cleaning fluid at high flow rates out of the drill string into the casing above the liner, at or adjacent the top edge of the liner.

Once such device that is known for carrying out this operation comprises a hollow body member and in order to change the direction of flow between the bottom of the liner and the top edge of the liner, spherical balls are dropped down the drill-string to open or close valves in the device.

However, there are a number of disadvantages associated with this apparatus. In particular, the length of time associated with the spherical balls falling from the surface to the device through a drill-string which is perhaps a few thousand feet in length can take 25 to 30 minutes. Hence, there is a problem with co-ordinating

the arrival of the spherical ball at the apparatus to coincide with the arrival of the required cleaning fluid at the apparatus. It is also necessary to ensure that the increasing and decreasing flow rates associated with the liner and the casing clean out are co-ordinated with the arrival of the spherical ball at the apparatus.

In addition, it is generally necessary to repeat the cleaning out of the liner and the casing a number of times with different cleaning fluids until a situation is obtained in which the last clean out is carried out with sea water. Hence, it is necessary to be able to repeatedly operate the apparatus to divert flow between the lower end and upper end of the liner a number of times. With the apparatus described above there is the disadvantage that the apparatus is designed so that each spherical ball that is dropped down the drill-string changes the direction of clean-out liquid flow either from the lower end of the liner to the upper end or from the upper end of the liner to the lower end of the liner. Hence, the number of times which this apparatus can be used to cycle fluid between the lower and upper ends of the liner is limited by the design of the device and when the spherical balls have been used or the tool is full with spherical balls and cannot be cyclically operated further, it is necessary to extract the drill-string from the borehole in order to recover the device and remove the spherical balls from the device.

In addition, there is also the danger that the spherical balls may not properly engage with the device and the risk that the device will not operate correctly.

In accordance with the present invention, there is provided apparatus for circulating fluid in a borehole, the apparatus having a fluid inlet and a first fluid outlet, the first fluid outlet communicating with the fluid inlet for throughflow of fluid through the apparatus, and the apparatus including:-

a body member having a second fluid outlet;

an isolation means movably mounted on the body member for movement between an open position in which fluid introduced into the apparatus through the fluid inlet may flow out of the second outlet, and a closed position in which fluid is substantially prevented from flowing out of the second outlet; and

actuating means connected with one of the body member or the isolation means for coupling to a formation in the borehole to provide resistance to movement of the actuating means with respect to the formation, whereby movement of the other of the body member or the isolation means relative to the formation causes relative movement between the isolation means and the body member to move the isolation means between its open and closed positions.

An advantage of the invention is that by providing an isolation means which is movable between a closed position and an open position and an actuating means which may be coupled to a formation in the borehole, circulation of fluid can be redirected by movement of one of the body member or isolation means relative to the formation.

Typically, the formation may be a shoulder portion in the borehole. Alternatively, the formation may be the bottom of the borehole, in which case the actuating means may be coupled to the formation by a string, such

as a drill string, on which the apparatus is run into the hole.

The apparatus may further include biasing means to bias the isolation means to the closed or open position. Typically, the biasing means is mounted on the body member. In the preferred example of the invention, the isolation means is biased to the closed position by the biasing means.

In one example of the invention, the isolation means prevents fluid passing through the second outlet by obturating the second outlet and typically, the isolation means could comprise a sleeve mounted on the body member. The isolation means may be mounted on the outside surface of the body member or on an inside surface of the body member.

In another example of the invention, the body member may include a by-pass channel and in the closed position the isolation means obturates the entrance and/or exit to the by-pass channel or the second outlet, while in the open position fluid may by-pass the isolation means by passing through the by-pass channel to reach the second outlet.

Preferably, the second outlet may comprise a number of apertures in the body member which communicate with the inlet and typically, the apertures may be distributed circumferentially around the outer surface of the body member.

Preferably, the fluid inlet and the first outlet are defined by a longitudinal throughbore in the body member and typically, the second outlet is defined by

at least one transverse bore extending from the throughbore to the outer surface of the body member.

Typically, the cross-sectional area of the second outlet is greater than the cross-sectional area of the first outlet.

Preferably, where the isolation means comprises a sleeve, the sleeve has a number of apertures therein which communicate with the second outlet when the isolation means is in the open position.

Preferably, the second outlet is designed to communicate with the apertures in the sleeve irrespective of the circumferential orientation of the sleeve with respect to the second outlet. Typically, this may be provided by a circumferentially extending groove on the outer surface of the body member which communicates with the second outlet and is aligned with the apertures in the sleeve when the isolation means is in the open position. Alternatively, this could be designed by providing a circumferentially extending groove on the inside of the sleeve which communicates with the apertures in the sleeve and aligns with the second outlet when the isolation means is in the open position.

Typically, movement of one of the body member or the isolation means towards the bottom of the borehole when the actuating means is coupled to the formation causes movement of the isolation means from the closed to the open position.

Typically, the actuating means may comprise a shoulder which contacts a shoulder portion in the borehole.

Preferably, the shoulder portion in the borehole may be provided by the upper edge of a liner installed in the borehole.

Preferably, a shoulder on the isolation means may have the surface which contacts the shoulder in the borehole and may have hard facing applied to it. The advantage of applying hard facing in this manner is that if the top edge of the liner has been damaged accidentally by running tools in and out of the liner, the hard facing can be used to redress the upper edge of the liner to ensure that the actuating means correctly engages with the top edge of the liner. Typically the hard facing could comprise tungsten carbide.

Preferably, the cross-sectional area of the second outlet in the body member is greater than the total cross-sectional area of the apertures in the sleeve. This has the advantage that wear of the apertures in the sleeve is more likely to occur than wear of the second outlet and, hence the life of the body member is increased.

Preferably, the apertures in the sleeve are designed to direct the fluid exiting the second outlet in an upwards direction into the casing.

Two examples of apparatus for circulating fluid in a borehole in accordance with the invention will now be described with reference to the accompanying drawings, in which:-

Fig. 1 is a partial cross-sectional view through a first example of a circulating tool; and
Fig. 2 is a cross-sectional view through a second

example of a circulating tool.

Fig. 1 shows a circulation tool 1 which comprises a body member 2 which has a throughbore 3 with a diameter of approximately 2.7". End 4 of the body member 2 has a female threaded coupling 5 and end 6 of the body member 2 has a male threaded coupling 7. In the central section of the body member are located twelve circumferentially distributed holes 8 and each hole has a diameter of 5/8" which gives a total cross-sectional area for the twelve holes 8 of approximately 3.68 square inches.

Slidably mounted on the outside surface of the body member 2 is a sleeve 9 which is biased against the body member 2 by means of a helical spring 10. Located in the sleeve 9 are two vent holes 11, 12 which permit the equalisation of pressures outside the sleeve 9 with pressures between the sleeve 9 and body member 2 in order to permit movement of the sleeve 9 relative to the body member 2. Also located in the sleeve 9 are eighteen circulating ports 13. The circulating ports 13 each have a ½" diameter and therefore have a total cross-sectional area of approximately 3.53 square inches. Also mounted on the body member 2 to engage the sleeve 9 are five O-ring seals 14 which sealingly engage with the sleeve 9. On the inside of sleeve 9 adjacent the circulating ports 13 is an internal groove 15 formed in the inner surface of the sleeve 9.

Below the sleeve 9 is a spring tensioner ring 16 which is threadedly engaged with the body member 2 through a thread formation 17. A set screw 18 is provided to lock the spring tensioner 16 in position on the body member 2.

The spring tensioner ring 16 has an angled shoulder 19 to which hard facing in the form of tungsten carbide hard facing 20 is applied in four equally spaced circumferential locations on the shoulder 19. At the lower end of the sleeve 9, adjacent the spring tensioner ring 16, an actuating shoulder 21 is provided.

For assembly of the tool 1, the helical spring 10, which in this example has a length of 10½ inches and a spring rating of 1,680 lbs per inch, is slid onto the body member 2 over the end 6 and located between shoulder 21 and lug 22 on the body member 2. The O-rings 14 are located in their respective grooves and the sleeve 9 is then slid onto the body member 2, until shoulder 23 on the sleeve abuts against the lower end of the spring 10. The spring tensioner ring 16 is then slid over the end 6 of the body member 2 and the thread formations 17 engaged. The spring tensioner ring 16 is then screwed up to the lower end of the sleeve 9 and tightened to compress the spring 10 and move the spring and sleeve 9 to the position shown in Fig. 1. In the example shown, this will give a tension of approximately 1,500 lbs in the spring 10 when the apparatus is in the position shown in Fig. 1.

In operation, the tool 1 is connected via the male connector 7 to the upper end of a drill-string and further lengths of drill-pipe are connected to the upper end 4 of the tool 1 using the female connector 5. The drill-string and tool 1 are lowered into a borehole until the spring tensioner ring 16 enters the upper end of a liner in the borehole and shoulder 20 on the sleeve 9 rests against the upper edge of the liner.

If the upper edge of the liner in the borehole has been damaged and the spring tensioner ring will not enter the liner, then the hard facing 19 on the shoulder 18 of the spring tensioner ring 16 will contact the damaged sections of the liner and rotation of the drill-string will cause rotation of the spring tensioner ring 16 to redress the upper edge of the liner by the abrasive action of the hard facing 19 on the upper edge of the liner.

The tension of the spring 10 when the sleeve 9 is in the position shown in Fig. 1 is such that the shoulder 20 can contact the upper edge of the liner without causing compression of the helical spring 10 and movement of the sleeve 9 upwards. Hence, initially the tool when the shoulder 20 contacts the upper edge of the liner remains in the position shown in Fig. 1.

In this position, the holes 8 in the body member 2 are obturated by the sleeve 9 and fluid can be pumped through the bore 3 in the tool 1 via the drill-string to exit the tool 1 through the end 6 into the drill-string below. Hence, fluid is pumped down the drill-string to the lower end of the liner to clean out the liner below the tool 1.

After the liner has been cleaned out, sufficient load is applied to the body member of the tool 1 to overcome the tension in the helical spring 10 and to cause movement of the body member 2 into the liner while the sleeve 9 rests on the upper edge of the liner. Travel of the sleeve 9 on the outside surface of the body member 2 is limited by shoulder 25 on the sleeve 9 which abuts against the lug 22 on the body member. This helps prevent the spring 10 becoming spring bound.

When the shoulder 25 abuts against the lug 22 the groove 15 is adjacent the holes 8 in the body member 2 so that the holes 8 communicate with the circulating ports 13.

When the sleeve is in this second open position, fluid is free to pass from the throughbore 3 of the body member 2 and out through the holes 8 and circulating ports 13 into the casing without entering the liner. The upward facing direction of the circulating ports 13 helps to reduce the possibility of any damage occurring to the casing due to the fluid exiting the circulating ports 13 horizontally.

The advantage of the groove 15 is that irrespective of the orientation of the circulating ports 13 relative to the holes 8, fluid will pass through the holes 8 and out of the circulating ports 13 via the groove 15.

Furthermore it will be noted that the total cross-sectional area of the circulating ports 13 is less than the total cross-sectional area of the holes 8. Hence, any wear due to fluid flow is more likely to occur on the circulating ports 13 which will only require replacement of the sleeve 9. As the sleeve 9 is less costly than the body member 2 this gives a cost efficient design.

In order to start circulating fluid to the bottom of the liner again, the holes 8 can be obturated by reducing the load on the body member 2 of the tool 1 so that the tool 1 reverts to the position shown in Fig. 1 and fluid can be circulated through the drill-string to the lower end of the liner for cleaning out the liner again.

In addition, a pressure operated valve could be coupled to the lower end 6 of the body member to positively isolate the lower length of drill-string from the through bore 3. As the flow rates of fluid will be higher when cleaning out the casing, such a valve could be designed to close above a given threshold pressure and open when pressure falls below this threshold.

Fig. 2 shows a second example of a circulating tool 30 which comprises a body member 31. The body member 31 comprises a top sub 32 having a female threaded end 33. Threadedly engaged with the lower end of the top sub 32 is a main sub 34 and threadedly engaged with the lower end of the main sub 34 is a bottom sub 35. Slidably mounted within the central sub 34 is a piston assembly 36 which has a throughbore 37 in its upper end. Threadedly connected to the piston assembly 36 is the upper end of an inner mandrel 38. The lower end of the mandrel 38 protrudes from the end of the bottom sub 35 and the lowermost end of the mandrel 38 has a male threaded connection 39. The top sub 32 has a throughbore 40 which communicates with the throughbore 37 in the piston assembly 36 and a throughbore 41 in the mandrel 38.

As shown in Fig. 2, the main sub 34 has a channel member 42 located on its outer surface and which defines a channel 43 which extends from ports 44 in the side wall of the main sub 34 to ports 45 also in the side wall of the main sub 34. Located further down the main sub 34 are outlet ports 46 in the lower end of the main sub 34.

In use, the tool 30 is coupled into a drill string at the appropriate depth and may also have a pressure

operated valve coupled to the connection 39 of the mandrel 38.

In order to pump fluid through the tool 30 to exit through the bore 41 in the mandrel 38, the drill string above the top sub 32 is lifted and the weight of the drill string below the mandrel 38 causes the piston assembly 36 and the inner mandrel 38 to stay stationary with respect to the borehole and the body member 31 moves upwards until the top end of the bottom sub 35 abuts the lower end of the piston assembly 36. In this position the outlet ports 46 are obturated and fluid within the tool 30 is prevented from exiting through the ports 46 so that fluid pumped into the tool 30 must pass through the bore 41 and into the drill string below the tool 30 to the lower end of the liner to clean out the liner below the tool 30.

After the liner has been cleaned out, the drill string above the tool 30 can be lowered causing the body member 31 to move relative to the piston assembly 36 and mandrel 38 until the lower end of the bottom sub 35 rests against shoulder 47 on the mandrel 38, so that the tool 30 is in the position shown in Fig. 2. In this position, fluid pumped into the tool 30 may by-pass the piston assembly 36 by means of the ports 44, 45 and the channel 43 to enter an annulus 48 between the main sub 34 and the mandrel 38. Hence, fluid may pass out of the outlet ports 46 to the casing without entering the liner.

The advantage of tool 30 shown in Fig. 2 is that it does not require a shoulder on the top of the liner in order to actuate the tool, as the tool may be actuated by resting the end of the drill string on the bottom of

the borehole and increasing or decreasing the tension appropriately in order to move the body member 31 up or down with respect to the piston assembly 36 and the mandrel 38. However, it would also be possible to use the tool 30 in combination with a shoulder in the borehole, such as the top of a liner by connecting a tool with a shoulder, such as the spring tensioner ring 16 shown in Fig. 1, around the mandrel 38.

Hence, the invention has the advantages of permitting circulation of fluids to separate regions in a borehole by increasing or decreasing the load exerted on the tools 1, 30 in the borehole. Hence, the tools 1, 30 have the advantage of operating when the load is increased or decreased without any effective time delay and also have the advantage that they facilitate circulation of the fluid between the two regions repeatedly without any limitation on the number of times recirculation can be achieved.

Modifications and improvements may be incorporated without departing from the scope of the invention.

CLAIMS

1. Apparatus for circulating fluid in a borehole, the apparatus having a fluid inlet and a first fluid outlet, the first fluid outlet communicating with the fluid inlet for throughflow of fluid through the apparatus, and the apparatus including:-

a body member having a second fluid outlet;

an isolation means movably mounted on the body member for movement between an open position in which fluid introduced into the apparatus through the fluid inlet may flow out of the second outlet, and a closed position in which fluid is substantially prevented from flowing out of the second outlet; and

actuating means connected with one of the body member or the isolation means for coupling to a formation in the borehole to provide resistance to movement of the actuating means with respect to the formation, whereby movement of the other of the body member or the isolation means relative to the formation causes relative movement between the isolation means and the body member to move the isolation means between its open and closed positions.

2. Apparatus according to claim 1, wherein the actuating means comprises a shoulder which engages a shoulder portion in the borehole.

3. Apparatus according to claim 1 or claim 2, wherein the isolation means obturates the second outlet when in the closed position.

4. Apparatus according to any of the preceding claims, wherein the body member includes a channel which extends across the isolation means when the

isolation means is in the open position.

5. Apparatus according to any of the preceding claims, wherein the fluid inlet and the first outlet are co-axial and the second outlet is transverse to the fluid inlet and the first outlet.

6. Apparatus according to any of the preceding claims, wherein the cross-sectional area of the second outlet is greater than the cross-sectional area of the first outlet.

7. Apparatus according to any of the preceding claims, wherein the isolation means comprises a sleeve.

8. Apparatus according to any of the preceding claims, wherein movement of one of the body member and the isolation means towards the bottom of the borehole, with the actuating means coupled to the formation moves the isolation means from the closed to the open position.

9. Apparatus according to any of the preceding claims, wherein the actuating means is connected with the isolation means and movement of the body member relative to the formation causes movement of the isolation means between the open and closed positions.

10. Apparatus for circulating fluid in a borehole, substantially as hereinbefore defined with reference to the accompanying drawings.

P ents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

17.

Application number
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Relevant Technical Fields

(i) UK Cl (Ed.M) E1F (FGL, FLJ, FLP)

(ii) Int Cl (Ed.5) E21B

Search Examiner
D J HARRISON

Date of completion of Search
16 FEBRUARY 1994

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant following a search in respect of Claims :-
1 TO 10

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 545271 A	(CUTHILL & OIL WELL ENGINEERING CO) - whole document, but see particularly page 3 lines 73-94	1, 3, 5, 7, 9
X	US 4637471 A	(SODERBERG) - whole document	1, 5, 6, 9
X	US 4315542 A	(DOCKINS Jr) - whole document	1, 3, 5, 7, 9
X	US 3907046 A	(GAYLORD) - whole document, but see particularly column 4 lines 15-30	1, 3, 5, 7, 8, 9

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